Real-time Bayesian Guided Surveillance for Epidemics

Chris Jewell (chris.jewell@warwick.ac.uk), Gareth Roberts
Centre for Research in Statistical Methodology, University of Warwick

Introduction

In livestock epidemics, a mainstay of reducing the capacity of an infected premises (IP) to transmit disease is reducing the infection to detection time. This is typically achieved by active surveillance: following up known contacts with the infected premises (IP), and actively patrolling designated surveillance zones.

Ideally, enough resource would be available to perform all necessary surveillance. However, resources are often constrained and surveillance teams must be targeted to those premises considered to be **high risk**. Deciding on high risk premises is difficult, as the epidemiological characteristics of the disease often determine the most important transmission mechanisms.

Here we use a simulated outbreak of a notifiable disease in the GB poultry industry to demonstrate how real-time Bayesian analysis of an epidemic can be used to effectively target active surveillance.

Aims

- To use **real-time Bayesian analysis** of case-reporting and contact tracing data gathered during an epidemic to measure transmission dynamics, and thereby target active disease surveillance.
- By targeting surveillance, cases may be detected earlier, reducing the potential for further disease transmission, and therefore the extent and duration of an epidemic.

Methods

Our existing Bayesian framework for real time inference and prediction for epidemics is used to generate probabilities that premises are harbouring undetected disease (see below).

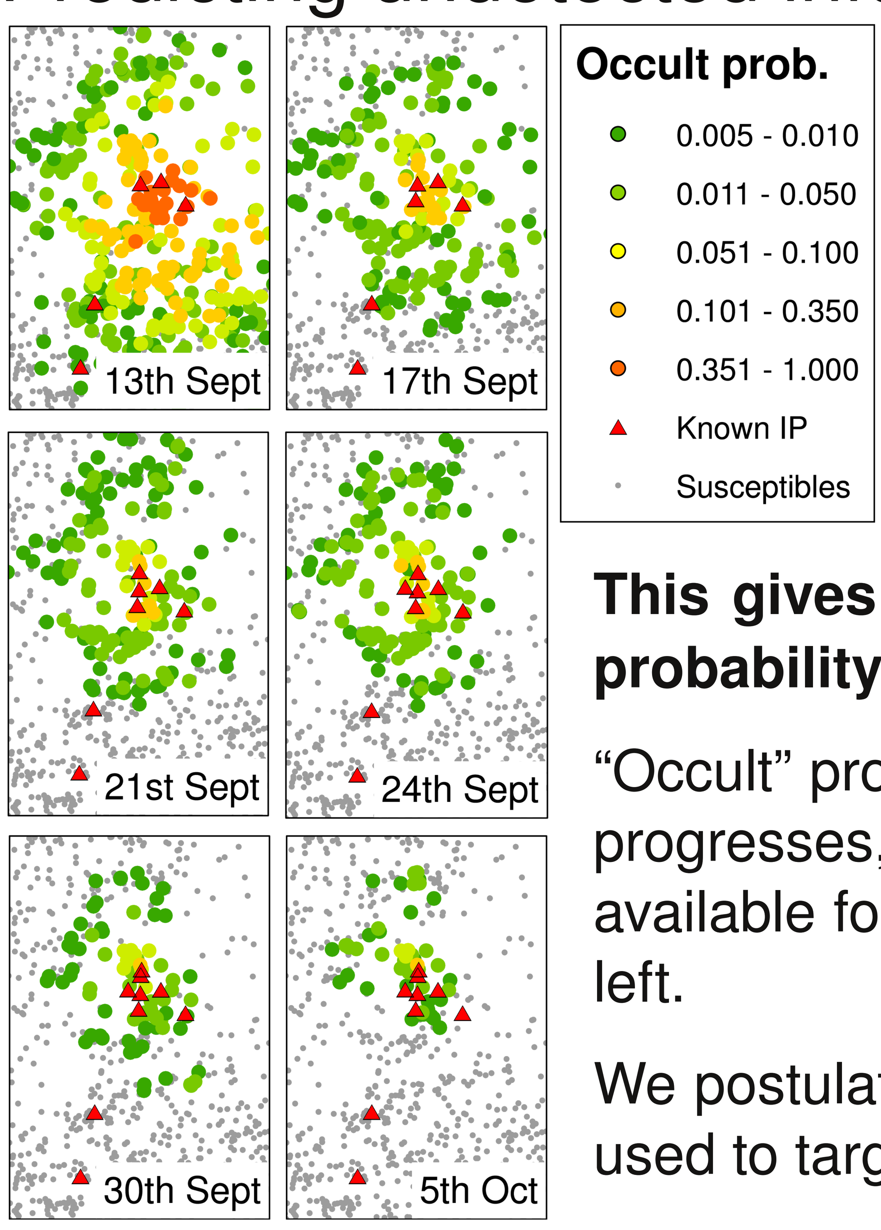
We extend this framework to incorporate contact tracing behaviour using a recently developed **data-determined mixed likelihood** technique[1].

Data: GB Poultry Register extract, 2006.

Covariates: Premises location, and major production type; feedmill, abattoir, and company networks.

Observations: Case detection time; time at end of cull; contact tracing data (source, destination, time, type).

Predicting undetected infections[2]



In the epidemic inference process, the presence of undetected (occult) infections is predicted probabilistically using rjMCMC on a Bayesian SINR model.

This gives each *presumed* susceptible a probability of *actually* being infected.

"Occult" probabilities evolve as the epidemic progresses, and more data becomes available for analysis. This is shown on the left.

We postulate that occult probabilities can be used to target surveillance.

References

1. Jewell CP (2009) Real-time Inference and Risk-Prediction for Notifiable Diseases of Animals. *PhD Thesis.* Lancaster University. go.warwick.ac.uk/stats/staff/research/jewell/thesis.pdf

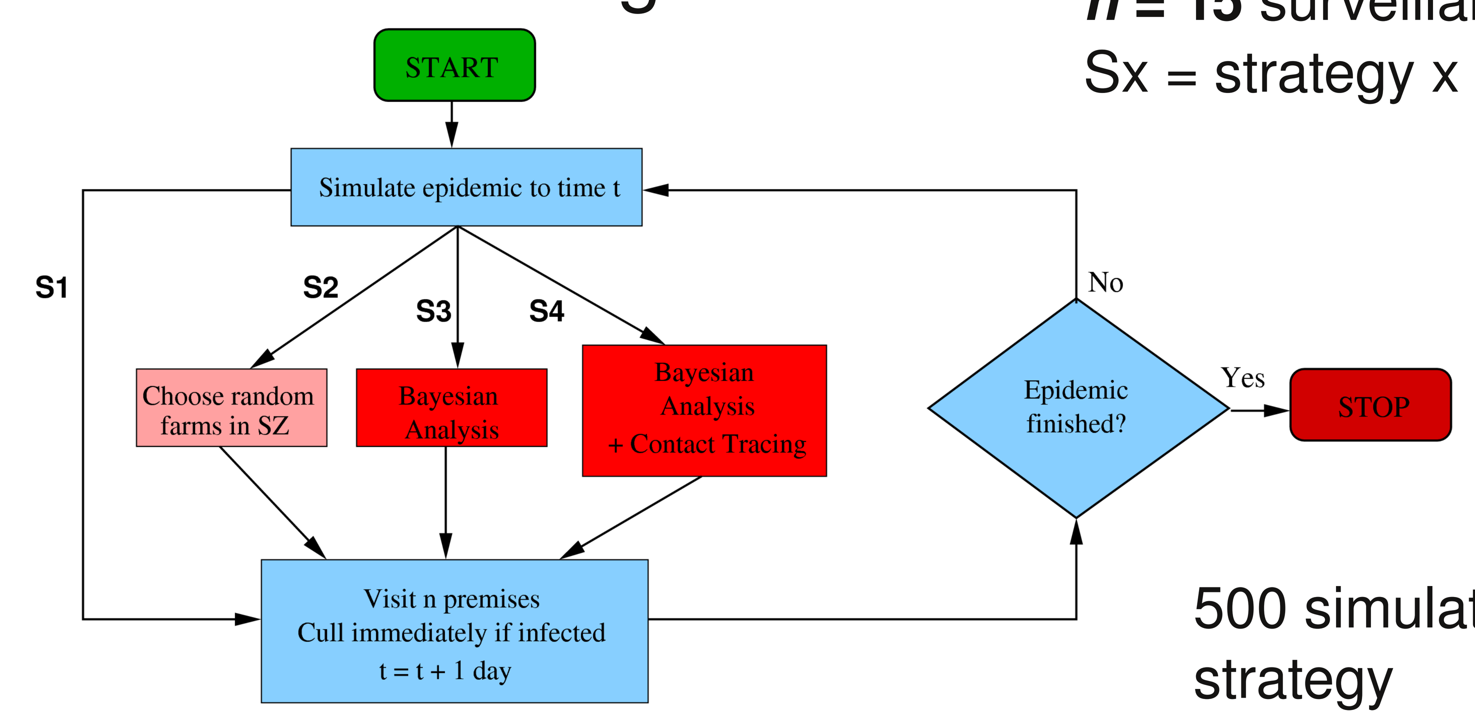
2. Jewell CP, Keeling MJ, Roberts GO (2009) Predicting undetected infections during the 2007 foot and mouth disease outbreak. *JRS Interface* **6**:1145-51

Comparison of surveillance strategies

1. **Passive** – no active surveillance. Case detection relies on SOS calls from farmers.
2. **Random** – survey *n* premises at random within the surveillance zone.
3. **Bayes** – use Bayesian guided surveillance to survey *n* high occult probability premises. Contact tracing not available.
4. **Bayes CT** – as (3), but using contact tracing data obtained from detected IPs.

Disease control algorithm

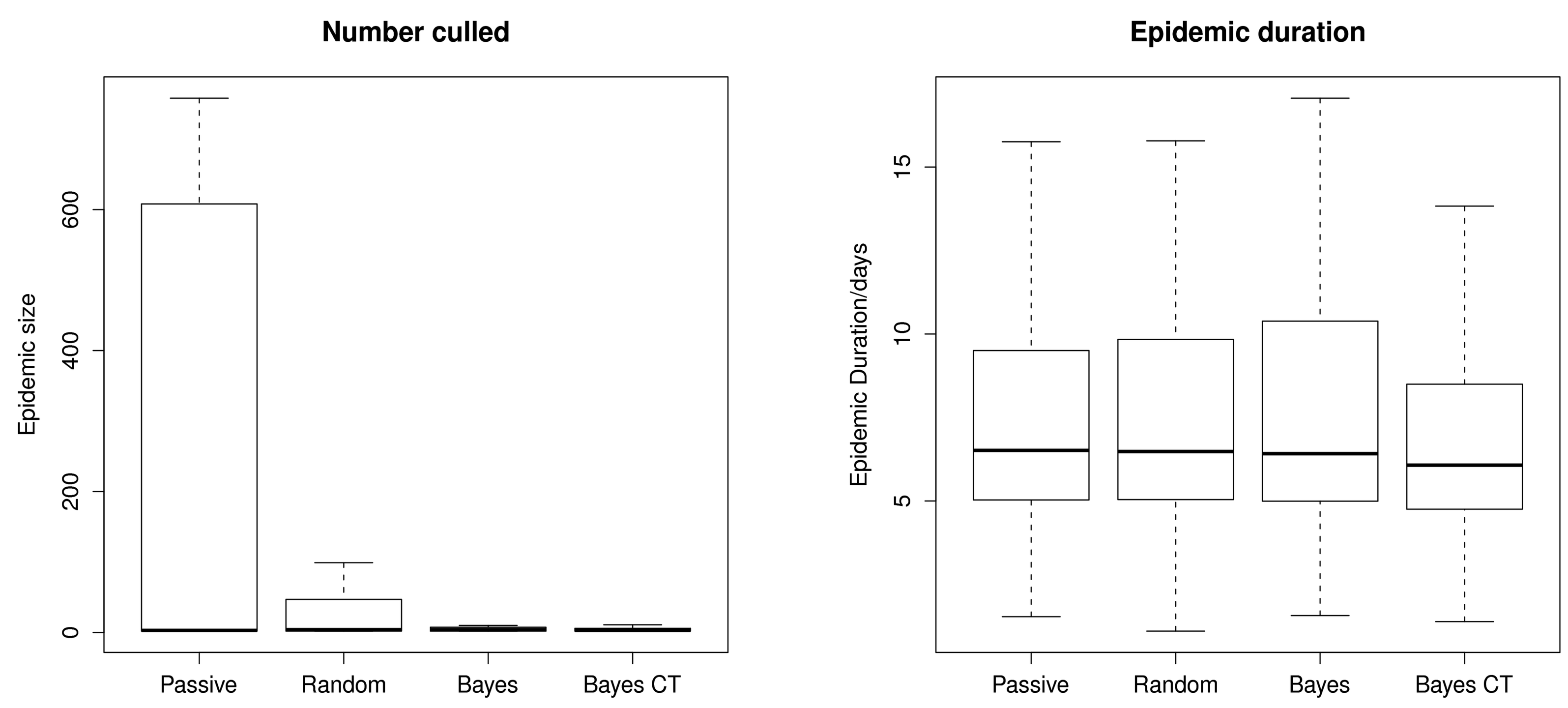
***n* = 15** surveillance teams
Sx = strategy x (as above)



500 simulations per strategy

Results

Distributions of final number of culled premises and epidemic duration under the 4 surveillance strategies.



Surveillance:	Passive	Random	Bayes	Bayes + CT
Mean # culled (SD)	74.9 (210)	42.7 (148)	18.7 (83.1)	7.04 (34.5)
Mean duration (SD)	17.9 (32.2)	13.3 (22.2)	8.91 (7.81)	8.38 (8.49)

Conclusions

- **Bayesian guided surveillance** targeting can be highly effective in optimising epidemic control tactics to minimise the number of culled premises.
- **Contact tracing** provides a significant increase in targeting accuracy, and should be provided to analysts in real-time in conjunction with case reporting.
- Because it bases predictions on **current data**, this method will be useful in adapting targeted surveillance to changes in epidemic behaviour as and when they occur.
- **Future**: is surveying the highest occult probabilities optimal? Rôle of network centrality? Testing against a "more realistic" control strategy – Defra, please talk to us!

Thanks to: Dr Rob Christley and Defra for provision of the data
BBSRC and NIHR for funding.